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(54) Title: MEASURING THE IN SITU STATIC FORMATION TEMPERATURE

(57) Abstract: Measuring the in situ temperature of a formation traversed by a borehole comprising lowering to a predetermined position in the borehole a tool that comprises a central conduit having an inlet an dbeing provided with a temperature sensor in contact with the fluid, means for analysing the fluid, and means for discharging fluid; allowing only formation fluid to pass through the central conduit; analysing the formation fluid; and measuring the temperature when the formation fluid is substantially uncontaminated.

MEASURING THE IN SITU STATIC FORMATION TEMPERATURE

The present invention relates to measuring the in situ static formation temperature in a well during a drilling stage. Ceasing circulation also refers to shutting-in the borehole. Ceasing circulation leaves the borehole filled with drilling mud, and the temperature of the drilling mud will in general differ from the temperature of the undisturbed formation.

One way of measuring this temperature is lowering a thermometer into the borehole filled with drilling mud and recording the temperature at a predetermined depth as a function of time (Δt) after ceasing circulation. The thermometer can be a self-contained recording temperature or a surface-recording thermometer. When the temperature is constant with time, one assumes that this constant temperature is the in situ static formation temperature. However, this method is time consuming.

An improvement of the above-described method is the following method. In this method the temperature is plotted versus $\log((tk+\Delta t)/\Delta t)$, wherein tk is the circulation time and Δt is the time after ceasing circulation. The result is extrapolated to $\log((tk+\Delta t)/\Delta t)$is substantially equal to zero, which means that the circulation time is negligible compared to the time after ceasing circulation. The extrapolated temperature is then assumed to be the in situ static formation temperature.

However, mistakes in the circulation time could make a large effect on the extrapolated temperature. Such a mistake is easily made, for example when after completing a drilling stage the driller pulls the drill bit up a couple of hundreds of meters, and continues circulation

for several hours to clean the bit before shutting in the borehole. In which case he will report a circulation time that is the sum of the circulation time needed to drill the particular stage and the time required for cleaning the drill bit. Whereas in order to evaluate the temperature record, the circulation time should be the circulation time needed to drill the particular stage.

It is an object of the present invention to provide a more accurate measurement of the in situ static temperature.

To this end the method of measuring the in situ static temperature of a formation traversed by a borehole according to the present invention comprises the steps of

a) lowering to a predetermined position in the borehole a tool that comprises a central conduit having an inlet and being provided with a temperature sensor in contact with the fluid, means for analysing the fluid, and means for discharging fluid;

b) making an exclusive fluid communication between the formation and the inlet of the central conduit;

c) allowing formation fluid to pass through the central conduit;

d) analysing the formation fluid; and

e) measuring the temperature when the formation fluid is substantially uncontaminated.

The invention will now be described in more detail. The first step of the method of measuring the in situ static temperature of a formation traversed by a borehole according to the present invention is lowering to a predetermined position in the borehole a tool that comprises a central conduit having an inlet and being provided with a temperature sensor in contact with the fluid, means for analysing the fluid, and means for discharging fluid. The predetermined position can be the bottom of the borehole, or a position in a formation

layer of which the in situ static formation temperature is to be measured. The tool is lowered into the borehole by means of for example a wireline.

Then an exclusive fluid communication is made between the formation and the inlet of the central conduit. In order to make the exclusive fluid communication, a probe is extended into the formation, wherein the outlet of the probe is in direct fluid communication with the inlet of the central conduit of the tool. Because the inlet of the probe is located in the formation, drilling mud present in the borehole cannot enter into the central conduit, an exclusive fluid communication is made between the formation and the inlet of the central conduit and thus the wellbore fluids are isolated.

Then formation fluid is allowed to pass through the central conduit. This is done with the aid of a pump, sucking the formation fluid via the probe into the central conduit and discharging the formation fluid from the central conduit. It will be understood that during drilling of the borehole, drilling mud will invade the formation. Therefore, when formation fluid is withdrawn, first drilling mud will be withdrawn, then a mixture of drilling mud and original formation fluid and finally uncontaminated formation fluid.

As it passes through the central conduit, the formation fluid is analysed to determine its composition.

Then the temperature is measured continuously until the formation fluid is substantially uncontaminated. Applicant had found that the temperature of the uncontaminated formation fluid is not just a temperature of a liquid, but it is precisely the in situ static formation temperature.

In practice both the temperature and the composition will be recorded, and the in situ static formation

temperature is the temperature that belongs to the substantially uncontaminated formation fluid.

Because in the method of the present invention the temperature of the uncontaminated formation fluid is measured, this method is more accurate than the known methods.

Moreover, the method according to the present invention can be carried out with a tool that is used to take samples of the formation fluids. Such a tool is for example the Modular Dynamics Formation Tester tool from Schlumberger. This tool also contains an accurate thermometer used to calibrate a pressure sensor, and the output of the accurate thermometer can be used in the method of the present invention. Other suitable tools known in the art are the repeat dynamic tester from Halliburton and the reservoir characterization instrument from Western Atlas.

In case the hydrocarbon reservoir fluid is a so-called heavy oil that is relatively viscous, it will be difficult to acquire a representative sample of the reservoir fluid. In order to obtain a representative sample, the step of making an exclusive fluid communication further includes activating a heating device arranged near the probe to heat the formation fluid.

Suitably, the probe is associated with a packer pad in an assembly, and the heating device is placed in the packer pad. Alternatively the heating device is arranged on the tool. The heating device may be a device generating microwaves, light waves or infrared waves. The heating device may also be an electrical heater, a chemical heater or a nuclear heater.

The method of the present invention can as well be applied in a cased borehole. In this case the step of lowering the tool into the borehole comprises two steps.

At first a perforation set is made through the casing wall into the formation at a location where the temperature needs to be established, wherein the perforation set comprises at least one perforation extending into the formation layer. Then the tool is lowered into the cased borehole. The tool is further provided with an upper and a lower packer arranged at either side of the inlet of the central conduit, wherein the central conduit opens below the lower packer or above the upper packer, and wherein the distance between the the upper and the lower packer is larger than the height of a perforation set.

Making an exclusive fluid communication then comprises setting the packers so that the perforation set is straddled between the packers.

CLAIMS

1. A method of measuring the in situ static temperature of a formation traversed by a borehole, which method comprises the steps of

a) lowering to a predetermined position in the borehole a tool that comprises a central conduit having an inlet and being provided with a temperature sensor in contact with the fluid, means for analysing the fluid, and means for discharging fluid;

b) making an exclusive fluid communication between the formation and the inlet of the central conduit;

c) allowing formation fluid to pass through the central conduit;

d) analysing the formation fluid; and

e) measuring the temperature when the formation fluid is substantially uncontaminated.

2. The method according to claim 1, wherein making an exclusive fluid communication between the formation and the inlet of the central conduit comprises extending into the formation a probe having an outlet that is in direct fluid communication with the inlet of the central conduit of the tool.

3. The method according to claim 2, wherein making an exclusive fluid communication further includes activating a heating device arranged near the probe to heat the formation fluid.

4. The method according to claim 1, wherein the formation is traversed by a cased borehole, wherein step a) comprises

a1) making a perforation set through the casing wall into the formation at a location where the temperature needs to be established;

a2) lowering the tool into the borehole to the perforation set, which tool is further provided with an upper and a lower packer arranged at either side of the inlet of the central conduit, wherein the central conduit opens below the lower packer or above the upper packer, and wherein the distance between the upper and the lower packer is larger than the height of a perforation set, and wherein step b) comprises setting the packers so that the perforation set is straddled between the packers.

INTERNATIONAL SEARCH REPORT

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 08424 A (WIN CUBED LTD ;CURLEY JOHN HOWARD (GB)) 6 March 1997 (1997-03-06) the whole document ---	1,2,4
X	US 3 417 827 A (SMITH FRANCIS M ET AL) 24 December 1968 (1968-12-24) column 3, line 36-65 column 4, line 38-43 figure 1 ---	1,4
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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